

What is claimed is:

1 1. A method for locating an object of interest, the method
2 comprising:
3 a) accepting at an observation point, signals
4 emanating from the object;
5 b) determining, for each of the accepted signals, at
6 least one of (A) an associated time of arrival, (B) an
7 amplitude, and (C) a direction of arrival;
8 c) determining at least two trace-back rays from the
9 observation point using the direction of arrival of
10 signals and topographical information;
11 d) determining candidate locations at crossings of
12 two or more trace-back rays;
13 e) determining a set of final candidate locations
14 from the determined candidate locations; and
15 f) determining the location of the object of interest
16 using the set of final candidate locations.

1 2. The method of claim 1 wherein the act accepting at an
2 observation point, signals emanating from the object,
3 includes screening the signals using a physical
4 characteristic of the signals.

1 3. The method of claim 1 wherein the act accepting at an
2 observation point, signals emanating from the object,
3 includes screening the signals using a bandpass frequency
4 filter.

1 4. The method of claim 1 wherein the act accepting at an
2 observation point, signals emanating from the object,

3 includes screening the signals using a signal amplitude
4 threshold.

1 5. The method of claim 1 wherein the act accepting at an
2 observation point, signals emanating from the object,
3 includes screening the signals using a signal-to-noise
4 threshold.

1 6. The method of claim 1 wherein the act accepting at an
2 observation point, signals emanating from the object,
3 includes screening the signals using an angle of arrival
4 threshold.

1 7. The method of claim 1 wherein the act accepting at an
2 observation point, signals emanating from the object,
3 includes screening the signals using a relative time of
4 arrival threshold.

1 8. The method of claim 1 wherein the act accepting at an
2 observation point, signals emanating from the object,
3 includes screening the signal using information carried by
4 the signals.

1 9. The method of claim 1 wherein the act of accepting at
2 an observation point, signals emanating from the object,
3 includes screening the signal using a unique identifier
4 carried by the signals and associated with the object.

1 10. The method of claim 1 wherein the act accepting at an
2 observation point, signals emanating from the object,
3 includes screening the signal using both (A) a physical

4 characteristic of the signals, and (B) information carried
5 by the signals.

1 11. The method of claim 1 wherein the act of determining,
2 for each of the accepted signals, at least one of (A) an
3 associated time of arrival, (B) an amplitude, and (C) a
4 direction of arrival, includes determining all of (A) an
5 associated time of arrival, (B) an amplitude, and (C) a
6 direction of arrival.

1 12. The method of claim 1 wherein the topographical
2 information includes sources of signal reflection.

1 13. The method of claim 1 wherein the topographical
2 information includes sources of signal diffraction.

1 14. The method of claim 1 wherein the topographical
2 information includes building surfaces.

1 15. The method of claim 1 wherein the topographical
2 information includes signal attenuation information.

1 16. The method of claim 1 wherein the act of determining a
2 set of final candidate locations from the determined
3 candidate locations includes eliminating at least some of
4 the candidate locations using the times of arrival
5 associated with the signals from which trace-back rays were
6 determined.

1 17. The method of claim 16 wherein a candidate location is
2 eliminated if the times of arrival are inconsistent with
3 expected times of arrival.

1 18. The method of claim 17 wherein a time of arrival is
2 determined to be inconsistent with an expected time of
3 arrival if they differ by more than a threshold difference.

1 19. The method of claim 1 wherein the act of determining a
2 set of final candidate locations from the determined
3 candidate locations includes eliminating at least some of
4 the candidate locations using the amplitudes associated
5 with the signals from which trace-back rays were
6 determined.

1 20. The method of claim 19 wherein a candidate location is
2 eliminated if the amplitudes are inconsistent with expected
3 amplitudes.

1 21. The method of claim 19 wherein an amplitude is
2 determined to be inconsistent with an expected amplitude if
3 they differ by more than a threshold difference.

1 22. The method of claim 1 wherein the act of determining a
2 set of final candidate locations from the determined
3 candidate locations includes eliminating at least some of
4 the candidate locations using both the times of arrival and
5 the amplitudes associated with the signals from which
6 trace-back rays were determined.

1 23. The method of claim 1 wherein the act of determining a
2 set of final candidate locations from the determined
3 candidate locations includes
4 i) determining if the times of arrival are
5 inconsistent with expected times of arrival;

6 ii) if it was determined that the times of
7 arrival are inconsistent with expected times of
8 arrival, then excluding the candidate location
9 from the set of final candidate locations; and
10 iii) if it was determined that the times of
11 arrival are not inconsistent with expected times
12 of arrival, then
13 A) determining if the amplitudes are
14 inconsistent with expected amplitudes, and
15 B) if it was determined that the amplitudes
16 are inconsistent with expected amplitudes,
17 then excluding the candidate location from
18 the set of final candidate locations.

1 24. The method of claim 1 wherein the act of determining
2 the location of the object of interest using the set of
3 final candidate locations includes

4 i) defining an area of accuracy including at
5 least one candidate location from the set of
6 final candidate locations, and
7 ii) determining the location of the object of
8 interest using the defined area of accuracy.

1 25. The method of claim 24 wherein the area of accuracy is
2 a circle of accuracy.

1 26. The method of claim 24 wherein at least two areas of
2 accuracy are defined, and
3 wherein the act of determining the location of the
4 object of interest uses a cardinality of each of the areas
5 of accuracy.

1 27. The method of claim 24 wherein at least two areas of
2 accuracy are defined, and

3 wherein the act of determining the location of the
4 object of interest includes

5 A) defining at least one cluster, each cluster
6 including locations of each of at least two areas
7 of accuracy, and

8 B) determining the location of the object of
9 interest using the at least one cluster.

1 28. The method of claim 27 wherein the act of determining
2 the location of the object of interest uses a location of
3 the at least one cluster.

1 29. The method of claim 27 wherein at least two clusters
2 are defined, each of the at least two clusters having an
3 associated diameter and

4 wherein the act of determining the location of the
5 object of interest uses the diameter of each of the at
6 least two clusters.

1 30. The method of claim 27 wherein at least two clusters
2 are defined, each of the at least two clusters having an
3 associated cluster cardinality, and

4 wherein the act of determining the location of the
5 object of interest uses the cluster cardinality of each of
6 the at least two clusters.

1 31. The method of claim 27 wherein at least two clusters
2 are defined, each of the at least two clusters having both
3 an associated diameter and an associated cluster
4 cardinality, and

5 wherein the act of determining the location of the
6 object of interest uses the cluster cardinality and the
7 diameter of each of the at least two clusters.

1 32. The method of claim 27 wherein at least two clusters
2 are defined, each of the at least two clusters having
3 - associated areas of accuracy, each of the
4 associated areas of accuracy having a cardinality,
5 - an associated diameter, and
6 - an associated cluster cardinality, and
7 wherein the act of determining the location of the
8 object of interest uses
9 - the cardinalities of the areas of accuracy
10 associated with each of the at least two clusters,
11 - the diameters associated with each of the at least
12 two clusters, and
13 - the cluster cardinalities associated with each of
14 the at least two clusters.

1 33. The method of claim 1 wherein the act of determining
2 the location of the object of interest using the set of
3 final candidate locations includes
4 i) defining a volume of accuracy including at
5 least one candidate location from the set of
6 final candidate locations, and
7 ii) determining the location of the object of
8 interest using the defined volume of accuracy.

1 34. The method of claim 33 wherein the volume of accuracy
2 is a sphere of accuracy.

1 35. The method of claim 33 wherein at least two volumes of
2 accuracy are defined, and
3 wherein the act of determining the location of the
4 object of interest uses a cardinality of each of the
5 volumes of accuracy.

1 36. The method of claim 33 wherein at least two volumes of
2 accuracy are defined, and
3 wherein the act of determining the location of the
4 object of interest includes
5 A) defining at least one cluster, each cluster
6 including locations of each of at least two
7 volumes of accuracy, and
8 B) determining the location of the object of
9 interest using the at least one cluster.

1 37. The method of claim 36 wherein the act of determining
2 the location of the object of interest uses a location of
3 the at least one cluster.

1 38. The method of claim 36 wherein at least two clusters
2 are defined, each of the at least two clusters having an
3 associated diameter and
4 wherein the act of determining the location of the
5 object of interest uses the diameter of each of the at
6 least two clusters.

1 39. The method of claim 36 wherein at least two clusters
2 are defined, each of the at least two clusters having an
3 associated cluster cardinality, and

4 wherein the act of determining the location of the
5 object of interest uses the cluster cardinality of each of
6 the at least two clusters.

1 40. The method of claim 36 wherein at least two clusters
2 are defined, each of the at least two clusters having both
3 an associated diameter and an associated cluster
4 cardinality, and

5 wherein the act of determining the location of the
6 object of interest uses the cluster cardinality and the
7 diameter of each of the at least two clusters.

1 41. The method of claim 36 wherein at least two clusters
2 are defined, each of the at least two clusters having

- 3 - associated volumes of accuracy, each of the
4 associated volumes of accuracy having a cardinality,
5 - an associated diameter, and
6 - an associated cluster cardinality, and

7 wherein the act of determining the location of the
8 object of interest uses

- 9 - the cardinalities of the volumes of accuracy
10 associated with each of the at least two clusters,
11 - the diameters associated with each of the at least
12 two clusters, and

13 the cluster cardinalities associated with each of the at
14 least two clusters

1 42. Apparatus for locating an object of interest, the
2 apparatus comprising:

- 3 a) an input for accepting at an observation point,
4 signals emanating from the object;

5 b) means for determining, for each of the accepted
6 signals, at least one of (A) an associated time of
7 arrival, (B) an amplitude, and (C) direction of
8 arrival;
9 c) means for determining at least two trace-back rays
10 from the observation point using the direction of
11 arrival of signals and topographical information;
12 d) means for determining candidate locations at
13 crossings of two or more trace-back rays;
14 e) means for determining a set of final candidate
15 locations from the determined candidate locations; and
16 f) means for determining the location of the object
17 of interest using the set of final candidate
18 locations.

1 43. The apparatus of claim 42 wherein the means for
2 determining, for each of the accepted signals, at least one
3 of (A) an associated time of arrival, (B) an amplitude, and
4 (C) a direction of arrival.

1 44. The apparatus of claim 42 wherein the topographical
2 information includes sources of signal reflection.

1 45. The apparatus of claim 42 wherein the topographical
2 information includes sources of signal diffraction.

1 46. The apparatus of claim 42 wherein the topographical
2 information includes building surfaces.

1 47. The apparatus of claim 42 wherein the topographical
2 information includes signal attenuation information.

1 48. The apparatus of claim 42 wherein the means for
2 determining a set of final candidate locations from the
3 determined candidate locations include means for
4 eliminating at least some of the candidate locations using
5 the times of arrival associated with the signals from which
6 trace-back rays were determined.

1 49. The apparatus of claim 42 wherein the means for
2 determining a set of final candidate locations from the
3 determined candidate locations include means for
4 eliminating at least some of the candidate locations using
5 the amplitudes associated with the signals from which
6 trace-back rays were determined.

1 50. The apparatus of claim 42 wherein the means for
2 determining a set of final candidate locations from the
3 determined candidate locations include means for
4 eliminating at least some of the candidate locations using
5 both the times of arrival and the amplitudes associated
6 with the signals from which trace-back rays were
7 determined.

1 51. The apparatus of claim 42 wherein the means for
2 determining a set of final candidate locations from the
3 determined candidate locations includes means for
4 i) determining if the times of arrival are
5 inconsistent with expected times of arrival;
6 ii) if it was determined that the times of
7 arrival are inconsistent with expected times of
8 arrival, then excluding the candidate location
9 from the set of final candidate locations; and

10 iii) if it was determined that the times of
11 arrival are not inconsistent with expected times
12 of arrival, then
13 A) determining if the amplitudes are
14 inconsistent with expected amplitudes, and
15 B) if it was determined that the amplitudes
16 are inconsistent with expected amplitudes,
17 then excluding the candidate location from
18 the set of final candidate locations.

1 52. The apparatus of claim 42 wherein the means for
2 determining the location of the object of interest using
3 the set of final candidate locations include means for
4 i) defining an area of accuracy including at
5 least one candidate location from the set of
6 final candidate locations, and
7 ii) determining the location of the object of
8 interest using the defined area of accuracy.

1 53. The apparatus of claim 42 wherein the means for
2 determining the location of the object of interest using
3 the set of final candidate locations include means for
4 i) defining a volume of accuracy including at
5 least one candidate location from the set of
6 final candidate locations, and
7 ii) determining the location of the object of
8 interest using the defined volume of accuracy.